Climate Change Invasions

by Teresa Jackson

The **Eastern Forest Environmental Threat Assessment Center** (EFETAC) uses modeling tools to assess the effects of climate change on invasive plant species. Climate change, as a major and growing disturbance agent, can have wide ranging effects on invasive species. Studies show that nonnative plants, especially invasive species, appear to thrive during times of climate change, as it creates niches and opportunities that promote invasion.

EFETAC researchers use a wide range of modeling and simulation approaches to make comprehensive comparisons between the habitats and geographical distributions of native and nonnative invasive plant species that help them to predict how expected climate change will affect the distributions of plant species in a given area. Geographic Information System (GIS) remote sensing tools are also used to assist the modeling process and to visually map out results that are easy to understand by both scientists and land managers.

"Effective management of invasive plant species requires a basic understanding of plant biology and ecology, particularly how species interact with each other and with the environment," says **Qinfeng Guo**, EFETAC research ecologist based in Asheville, NC. "This includes looking at how the life history and genetic traits of invasive plants may be linked to rapid and widespread invasion under current and projected future climate conditions."

Conducting both field and experimental research in diverse ecosystems across the United States and internationally allows scientists to collect life history and habitat data from both native and exotic regions that can be used to explain the current distribution of invasive plant species and to predict future spread under changing climate and land use change scenarios.

Many invasive plants have been introduced to the United States in a relatively short period of time.

Some nonnative invasive plants species such as cogongrass appear to thrive under climate change. (photo by Chris Evans, courtesy of Forestry Images)

Although some presently occupy smaller ranges relative to their native ranges, they have great potential to spread quickly and widely. Knowing which species are likely to do so based on their traits is critically needed to take early actions in prevention and control.

"The ultimate goal of EFETAC research is to preserve native biodiversity and to manage invasive species," says Guo.

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Recommended reading:

Guo, Q.; Ricklefs, R. 2010. **Domestic exotics and the perception of invisibility.** Diversity and Distributions. 16: 1034–1039.

Cogongrass infestation in a pine plantation. (photo by Chris Evans, courtesy of Forestry Images)

New Guide to Managing Invasive Plants

Many landowners are continuously plagued with unidentifiable annoying weeds and grasses that are resilient to herbicides. Some of these are nonnative invasives, plant species that have arrived without the natural predators and diseases that keep native plants in natural balance. Many have hybridized and increase across the landscape with little opposition.

Nonnative plants have hitchhiked their way into flower beds, gardens, and yards of landowners in the South for decades, invading and often harming forests and other natural areas by pushing out native plants and degrading wildlife habitat. These exotic plants often reduce forest productivity, wildlife diversity, and water quality and quantity.

The prevention and management strategies that landowners have been looking for to help control these unwanted resilient plants are now available in a new 120-page guide, ***A Management Guide for Invasive Plants in Southern Forests.*** The guide provides effective control prescriptions for 56 nonnative plants and plant groups and gives homeowners, gardeners, land managers, and others information needed to achieve land rehabilitation and restoration.

Jim Miller, an emeritus SRS research ecologist based in Auburn, AL, and one of the foremost authorities on invasive plants in the South, authored the guide with **Steven Manning**, president of Invasive Plant Control, Inc., and **Stephen Enloe**, weed management specialist at Auburn University.

Request your free copy today by sending your name and complete mailing address, along with book title, author, and publication number GTR–SRS–131 to: pubrequest@fs.fed.us, or by calling 828–257–4830. The 120-page guide is also available on the SRS Web site at www.srs.fs.usda.gov/pubs/36915.

Forest Ecosystem Stress in Real time

by Zoë Hoyle

Most climate change models predict drier and warmer conditions across the Southern United States, as well as other parts of the country, which may translate into more frequent and severe drought events. Drought not only impacts water supplies for humans but undermines the health of forest ecosystems by increasing susceptibility to insects, diseases, and wildfire. With an estimated 60 percent of the drinking water of the South coming from forested watersheds—and many forests already stressed—land managers need to start planning now to offset the impacts of climate change.

It seems to make sense to start with the forests that are under the greatest stress at a given time, but up until recently it has been difficult to pinpoint exactly where these are. A new resource, the **Remote Assessment of Forest Ecosystem Stress** (RAFES) network, developed by SRS researchers at the **Coweeta Hydrologic Laboratory** (Coweeta), will provide realtime data on climate impacts in at-risk forest ecosystems, giving managers the time they need to respond.

Traditional weather data on rainfall and temperature provide only a very general measure of the stress forest ecosystems may be experiencing.

RAFES tower at the Coweeta Hydrologic Laboratory in Otto, NC. (photo by Barry Clinton, USDA Forest Service)

"Current approaches are often conducted at too large a spatial scale, do not directly measure climate impacts on tree stress, and are not timely enough for managers to plan responses," says **Barry Clinton**, Coweeta research ecologist who's working on the RAFES project with research ecologist **Chelcy Ford** and project leader **Jim Vose**. "We're developing a fine-scale, realtime tree stress monitoring system that can be cost-effectively deployed across the landscape or strategically located in high-risk areas."

The researchers chose to focus on water availability as a stressor, considering its importance in regulating both forest stress and streamflow. The approach is to monitor levels of moisture-related stress through the continuous sensing of soil water content and availability, soil temperature, woody fuel moisture and temperature, xylem sap flux density—with precipitation, relative humidity, air temperature, and solar radiation as drivers. Data from the sensed parameters are transmitted hourly to the **National Oceanic and Atmospheric Administration**, **Geostationary Operational Environmental Satellite** (GOES), downloaded periodically and archived for analysis.

RAFES stations are made up of solar-powered sensor arrays installed at multiple sites across the Eastern United States. Data from these sensors transmitted in real time to the GOES can be retrieved from any location via the Internet. On select sites, data from the sensor arrays are linked with direct measures of physiologically based indices of tree water stress. Researchers are using these data to develop a PC-based analytical tool that allows managers to monitor and assess the severity of climate-related stress from sites on their own or comparable forests in real time.

So far nine sites have been brought online in the RAFES network at locations that range from the **Santee Experimental Forest** on the South Carolina coast to the **Crossett Experimental Forest** in southern Arkansas to the **Marcell Experimental Forest** in northern Minnesota. Other sites are located in the Southern Appalachians, the Piedmont and the coast of North Carolina. RAFES sites span forest ecosystem types, land use histories, and hydrologic gradients. More are on the way.

Eddy covariance tower installed last year at Coweeta to measure the flow of carbon dioxide and other gases above the forest canopy. The observations made with this system, which is separate from the RAFES system, are critical for detecting variations in carbon and nutrient gases in relation to climate change. (photo by Zoë Hoyle, USDA Forest Service)

"The locations of the first sites reflect a combination of leveraging existing infrastructure and site access," says Clinton. "Our approach to adding additional sites will be to identify forest ecosystems that are particularly susceptible to climate change-related stress. Our goals are to be able to provide spatially and temporally explicit early warnings for managers, and in the bigger picture, to provide realtime information on ecosystem responses to extreme climatic events across representative at-risk forest types—as well as to validate conditions detected with coarser scale data such as satellite imagery."

The RAFES network fits nicely within the framework of current Forest Service efforts to evaluate direct and indirect effects of climate change on forest ecosystems and develop tools and practices for adaptation and mitigation. "This approach is the first attempt to our knowledge to quantify such spatially and temporally explicit stress conditions," says Clinton. "It could prove to be a valuable asset to forest management decisionmaking in the face of predicted climate change."

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More Fuel for Fire?

by Susan Andrew

Fire has been a fact of life for millennia in the South, shaping the range and ecology of pine, certain oak, and palm forests. But along with shrinking polar ice and rising sea levels, there is general agreement among climate scientists that climate change will probably increase both the intensity and frequency of fire in the southern landscape.

In its 2007 assessment, the **UN Intergovernmental Panel on Climate Change** cited multiple studies that link the spread of wildfires to the warmer, drier conditions already found in many regions due to rising temperatures from climate change. General circulation models used for weather and climate forecasting predict that by the end of this century, there will be an overall warming and drying trend in a large portion of the subtropics and middle latitudes of the world, including the Southeastern United States—conditions that are expected to also bring an increase in wildfires.

Current SRS research confirms these predictions. A study published last year by **SRS Center for Forest Disturbance Research** researchers **Yongqiang Liu, John Stanturf,** and **Scott Goodrick** examines global and regional wildfire potential using the Keetch-Byram Drought Index (KBDI). This tool was developed in the 1960s by two SRS scientists and has become a widely used estimate of landscape fire potential. A high KBDI value means an increased flammability of organic material on the forest floor that contributes to greater fire intensity. With higher values of KBDI, wildland fires are more intense and spread faster.

SRS researchers calculated future KBDI for the region using projections of temperature and precipitation provided by a regional climate model. They found that fire potential increases across the South in the near future (2041 to 2070), most significantly during summer and fall. They also found an increase in the length of the fire season, with the greatest increase in the Appalachian Mountain region, where the current fire season of 4 months (July to October) is projected to grow to 7 months (April to October) by the end of this century.

"We're projecting an extended fire season, including in the Coastal Plain, where those afternoon thunderstorms that can help put out fires may have a delayed onset," says Goodrick. In addition, when they project forward towards the end of the century using a model that reproduces current conditions, "we see a slight increase in dryness in May and June—that's when a lot of our acres burn. A small change at that time of year means that we'll be fighting more significant

Climate change will probably increase both the intensity and frequency of fire in the southern landscape. (photo courtesy of the U.S. Fish and Wildlife Service)

SRS research meteorologist Yongqiang Liu measures smoke from a fire plume in the field. (photo by USDA Forest Service)

fires then. At the very time when we have our peak fire conditions, our conditions are going to be worse."

In another recent study by Liu and colleagues from Auburn University, the authors predict changes in fuel loads in response to projected changes in climate in the South for the period 2002 to 2050. The researchers found that by 2050, reduced precipitation will lead to a small decline in fuel load for the region as a whole because of reduced forest growth. This will be the case, the researchers argue, despite projections of increased forest growth driven by CO_2 availability and increased nitrogen deposition. However, this study revealed a lot of variability across the South when it comes to fuel loads, owing to different climate effects anticipated in various places. For instance, a decline in precipitation in the northern inland section of the region may lead to a 20-percent reduction in fuel load for the forests of Tennessee and Kentucky, while elevated precipitation and decreased daily mean temperatures in coastal areas of Virginia and the Carolinas may result in increased fuel loads there.

Burning to Reduce the Risk

SRS efforts to understand wildfire trends in a time of climate change can help define management options for mitigating impacts. One management option is prescribed burning, which reduces understory fuels, lowering the risk of wildfires. "Some case studies have shown that the number of wildfires in specific forests has decreased gradually in the past two decades with the increased use of prescribed burning," says Liu. "A need for more extensive use of this tool is expected in the future in the face of the projected increase in wildfire potential."

An oft-cited prediction for the South in a time of climate change is stronger and more frequent tropical storms. Goodrick says one area he's pursuing relates to how these storms and wildfires interact. After a major tropical storm, there's a lot more fuel on the ground, including whole trees knocked down by wind. But the result isn't always what you would expect. "In a moist climate, big logs don't necessarily dry out enough to be part of the fire problem," says Goodrick. "In some conditions they can actually help to reduce fire, because they're still too moist to burn the next year. More 'fuel' doesn't always mean more fire."

Goodrick sees a take-home message for forest managers here. "The standard management response after a major wind event is extensive salvage logging," he says. "But it may not be the best answer, because you may be removing something that can actually reduce fire."

"Wildfire is likely to play a larger role in southern ecosystems. The exact nature of that role will be determined by how the vegetation responds, and how fuel accumulation rates change," says Goodrick. "In the future, fire conditions are likely to be bad, but due to the possibility of lower fuel loads, they won't be as bad as they could have been. Yet even under the best foreseeable future, wildfire is still likely to be worse than it is today."

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Recommended reading:

Liu, Y.-Q.; Stanturf, J.; Goodrick, S. 2009. **Trends in global wildfire potential in a changing climate.** Forest Ecology and Management. 259: 685–697.

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Zhang, C.; Tian, H.; Wang, Yuhang [and others]. 2010. **Predicting response of fuel load to future changes in climate and atmospheric composition in the Southern United States.** Forest Ecology and Management. 260: 556–564.

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CRAFTING FUTURE FORESTS

by Zoë Hoyle

Successful restoration of longleaf pine forests requires frequent prescribed burning. (photo by USDA Forest Service)

Managing our national forests has always involved responding to disturbance—from weather, diseases and insects, wildfire, and now, the impacts of climate change. Since the National Environmental Policy Act (NEPA) passed in 1970, managing national forests has also involved taking into account what the public thinks about proposed plans and actions. In the past, conflicts among competing points of view during the NEPA process have often resulted in long delays and sometimes in the abandonment of proposed actions.

These days, there are even more plans and proposed actions for national forests in the offing, many of them orchestrated around the **Forest Service *National Roadmap for Responding to Climate Change***, a framework developed by the agency for long-term planning. To prepare for climate change impacts, the roadmap supports restoring forests to a healthy functioning condition, an aim that might seem to invite public applause rather than controversy, but on the ground, the actions intended to restore forests may not always be acceptable to everyone.

Take for example, longleaf pine restoration.

Before European settlement, longleaf pine forests covered over 90 million acres in the South. Today, barely 3 million acres remain. There's strong interest in restoring longleaf pine forests and their unique ecosystems, which are more resilient to insect attacks and hurricane winds than the loblolly forests that have largely replaced them. This resilience moves longleaf pine restoration from a good idea to an attractive strategy to address the impacts of climate change.

So what's the problem?

The South is a place of unabated population growth, where more and more people are building their homes near once remote forests. Bringing back longleaf pine into areas now forested with mixed pines and hardwoods requires frequent prescribed burning, which generates smoke that people who live nearby may not be willing to tolerate. Burning less frequently or only when smoke conflicts are unlikely means less fire, which will eventually defeat the restoration. In this case, uncertainty and the anticipation of conflict could lead managers to back off plans for longleaf pine restoration in certain areas as just too much trouble. If long-range planning could actually predict where such conflicts would or would not arise, our landscapes on the whole could be better managed.

Fortunately, SRS scientists have developed a new resource, the **Comparative Risk Assessment Framework and Tools** (CRAFT), to help natural resource managers and stakeholders work through land management decisions and find common ground, sometimes by coming up with unexpected solutions.

Virtual Common Ground

Headquartered at SRS, the **Eastern Forest Environmental Threat Assessment Center** (EFETAC) was formed in 2005 to develop new technology and tools to anticipate and respond to emerging eastern forest threats, and to deliver these tools to other scientists, managers, and stakeholders involved in natural resource planning and decisionmaking.

In fall 2009, EFETAC launched CRAFT as a user-friendly Web-based system designed to support natural resource managers in addressing the uncertainties inherent in land management decisions. Building on the NEPA framework, CRAFT offers a simple and comprehensive approach that teams of managers and stakeholders can use to look at the risks and tradeoffs associated with different management scenarios.

"It's all about tradeoffs," says **Steve Norman**, EFETAC research ecologist who helped develop CRAFT. "Before NEPA, land managers made decisions by focusing on individual threats or values. Today, even with NEPA in place, the broader effects that those decisions could have on other values are still difficult to predict. CRAFT is a way to tease out those broader values and infer likely consequences."

CRAFT was designed to capture this broader view of what's likely to happen in a given situation and to ensure that the values that are most likely to be affected are adequately considered. As its name indicates, CRAFT is about comparative risk assessment, allowing users to weigh the likely impacts to values—what they care about—based on the chance that the action will be successful. This approach provides ways to work through tradeoffs while formally taking uncertainty into consideration.

The process starts when a diverse group of stakeholders or a management team sits down at the table to examine values and address how they are affected by the problem at hand and possible solutions. Through the process, team members explore the probable and possible outcomes of different actions—including the decision not to act—while broadening their own understanding of conflicts, tradeoffs, and the uncertainties and unintended effects that follow from decision alternatives.

"When we developed CRAFT, we borrowed the best ideas we could find from the emerging fields of decision science and risk assessment," says Norman. "This included ways to organize values, vet cause and effect relationships, and formally model uncertainty and decision options."

To develop CRAFT, EFETAC partnered with the University of North Carolina Asheville's **National Environmental Modeling and Analysis Center** (NEMAC), which created a unique array of Web-based resources, including the CRAFTiPedia—a "wiki" style reference database and glossary. The CRAFT online tool can store and share the diagrams, text, tables, data, and models created during each decisionmaking project. NEMAC also provides assistance and training on using CRAFT.

Although designed to follow NEPA requirements, CRAFT can be used by a much broader range of audiences and for regional and even national-level issues. For example, in 2009, the first CRAFT workshop included people from the Forest Service, the National Oceanic and Atmospheric Administration's National Climatic Data Center, the City of Asheville, the Southern Group of State Foresters, and The Nature Conservancy, in an introductory exercise aimed at addressing climate change impacts on the Southern Appalachians.

The latest application of CRAFT involves the **Cohesive Wildland Fire Strategy**, a new multiagency wildfire strategy that aligns with the Forest Service roadmap for responding to the climate change that is projected to increase the frequency and extent of forest fires across the United States. Led by EFETAC's director **Danny Lee**, who helped develop CRAFT, the all-lands approach of the fire strategy has three main goals: using ecosystem restoration to build fire-adapted communities, building fire-adapted human communities by sharing knowledge and technical resources, and responding appropriately to wildfire.

"Applying CRAFT to address wildfire issues in the Southeast is exciting," says Norman. "Fire is necessary for the resilience of many southern ecosystems, and prescribed fire use can conflict with trends in urban development." CRAFT provides the framework to get at these issues and more—and just maybe some solutions no one's thought of yet.

CRAFT Web site:

CRAFT.forestthreats.org.

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Recommended reading:

Hicks, J.; Pierce, T. 2009. **CRAFTing better decisions: creating a link between belief networks and GIS.** ArcUser. Fall: 20–23.

Trees in Transition

by Stephanie Worley Firley

In forests as in life, the only constant is change. Forest species are ever adjusting to changing conditions resulting from seasonal fluctuations in temperature and precipitation, disturbances such as storms and wildfire, and interactions with other species. But typical temperature and precipitation patterns are now also changing; in some areas, climatic changes are occurring rather rapidly, which could pose a severe threat to forest trees. Whether tree populations adapt onsite to changing habitat conditions, shift their ranges to new suitable locations, or simply die out, the forests we know today—and the genetic makeup of the species within them—could be very different by the middle of the 21st century.

Kevin Potter collects cones from a Fraser fir tree on Mount Rogers in Virginia. As a high-elevation species, Fraser fir may be at particular risk from climate change. (photo courtesy of Kevin Potter, North Carolina State University)

Now researchers from the **Eastern Forest Environmental Threat Assessment Center** (EFETAC) are asking the question: In a future with a different climate, where might the trees be?

With support from the Forest Service **Forest Health Monitoring Program**, EFETAC ecologist **Bill Hargrove** and **North Carolina State University** cooperating scientists **Kevin Potter** and **Frank Koch** are collaborating to develop **Forecasts of Climate-Associated Shifts in Tree Species** (ForeCASTS). Using projections of future climate in combination with the concept of fine-scale ecoregions—land areas that share similar environmental characteristics such as soils, topography, and climate variables—the researchers are developing maps depicting future suitable habitat ranges for tree species within the United States as well as across the globe.

ForeCASTS maps can help scientists, land managers, and policymakers target tree species for monitoring and management activities by pinpointing locations where climate change pressures are likely to be most intense.

“The Forest Service has a long history of understanding that the seed source makes a huge difference in tree growth and performance,” says Hargrove. “ForeCASTS maps can ultimately be used to assess the risk to genetic integrity of North American forest tree populations.”

Parts of the current range of longleaf pine may become less suitable for the species as climate changes. (photo courtesy of Kevin Potter, North Carolina State University)

Potter adds, "The ForeCASTS project can help guide decisions about how and where to invest time and funds for conservation efforts." Conserving genetic variation is particularly important because it confers the evolutionary potential to adapt to change, reducing susceptibility to stressors like insects and pathogens in addition to climate change.

So far, the researchers have developed maps for 213 tree species under varying climate models and scenarios for the years 2050 and 2100, including "minimum required movement" maps that quantify the distances between existing habitat that may become unsuitable in the future and the nearest future suitable habitat. "The general trend, as we would expect, is for tree ranges to expand at least a little bit to the north, and to drop off at least a little bit at their southern edges," says Potter. "Looking at species with ranges that include the Southern Appalachians, the ForeCASTS maps show nearly all species decreasing their overall suitable habitat area."

The ForeCASTS maps are still provisional. As the project unfolds, the researchers are refining the available map products and adding additional species to the queue. They plan to identify closest "lifeboat" areas for tree species that may migrate from multiple locations as well as add measures of performance to determine where species may thrive in future projected habitat ranges. Later, the methods used in ForeCASTS could be employed to explore future distributions of invasive species to aid in proactive management of vulnerable forest ecosystems.

ForeCASTS:

www.forestthreats.org/tools/ForeCASTS

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Recommended reading:

Potter, K.M.; Hargrove, W.W.; Koch, F.H. 2010. **Predicting climate change extirpation risk for central and Southern Appalachian forest tree species.** In: Rentch, J.S.; Schuler, T.M., eds. Proceedings from the conference on ecology and management of high-elevation forests of the central and Southern Appalachian Mountains. Gen. Tech. Rep. NRS–P–64. Newtown Square, PA: U.S. Department of Agriculture Forest Service, Northern Research Station: 179–189.

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